



# Pneumatic Transfer System and Packing System for the Moon

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# Topics



**Need of Pneumatic Transfer & Packing System**



**Concept Designs**



**Pneumatic Transportation System**



**Packing System**



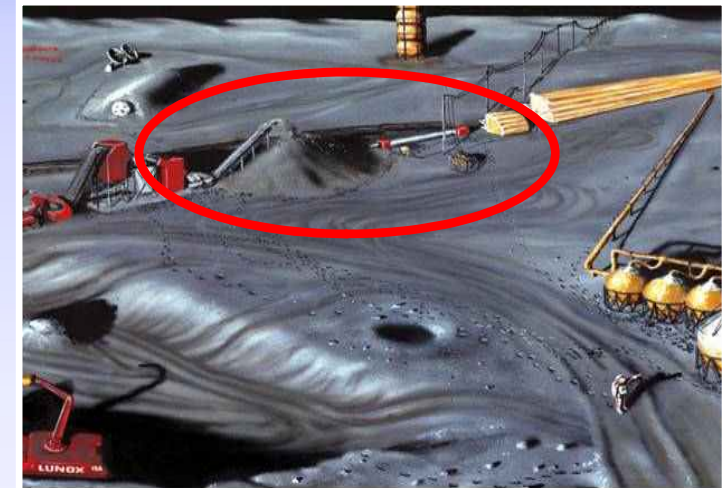
**Future Plan**

# Need of Pneumatic Transfer & Packing System

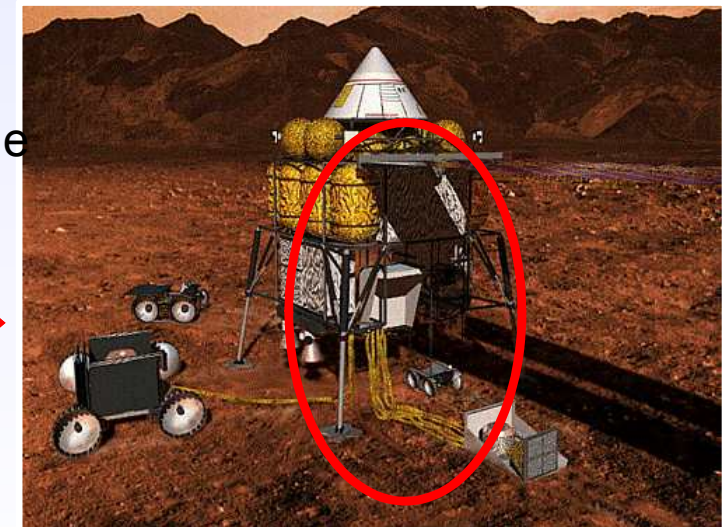
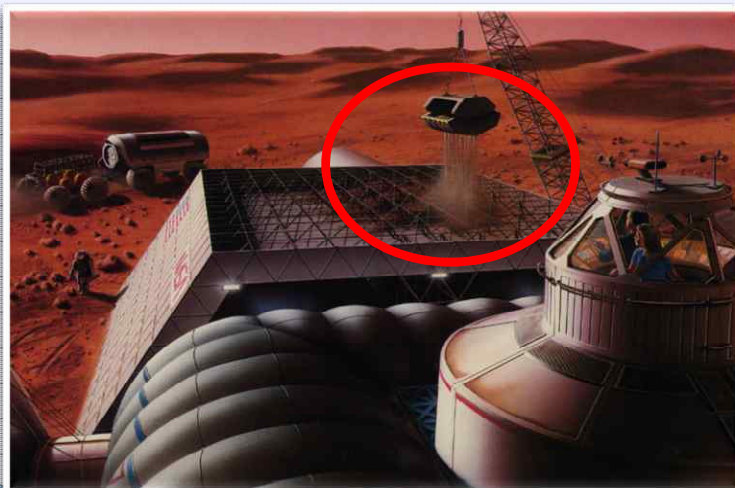
## Need of Pneumatic Transportation System



➤ Vehicle makes Dust



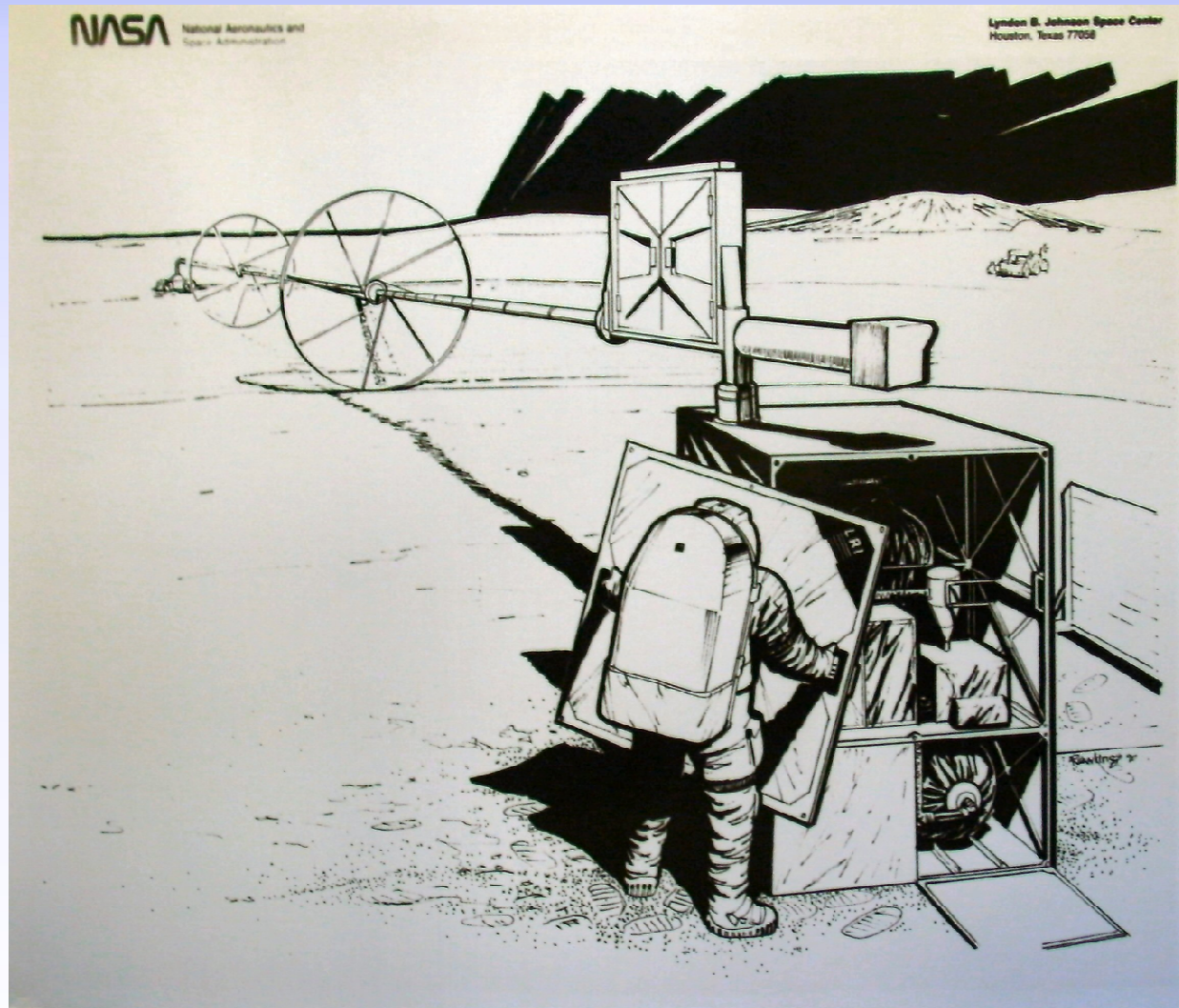
➤ Limits of transportation capacity by vehicle (depends on weight)





# Need of Pneumatic Transfer & Packing System

Small pneumatic mining system which rotates in a circle and can add sections of double-wall pipe in 1 meter increments from a magazine

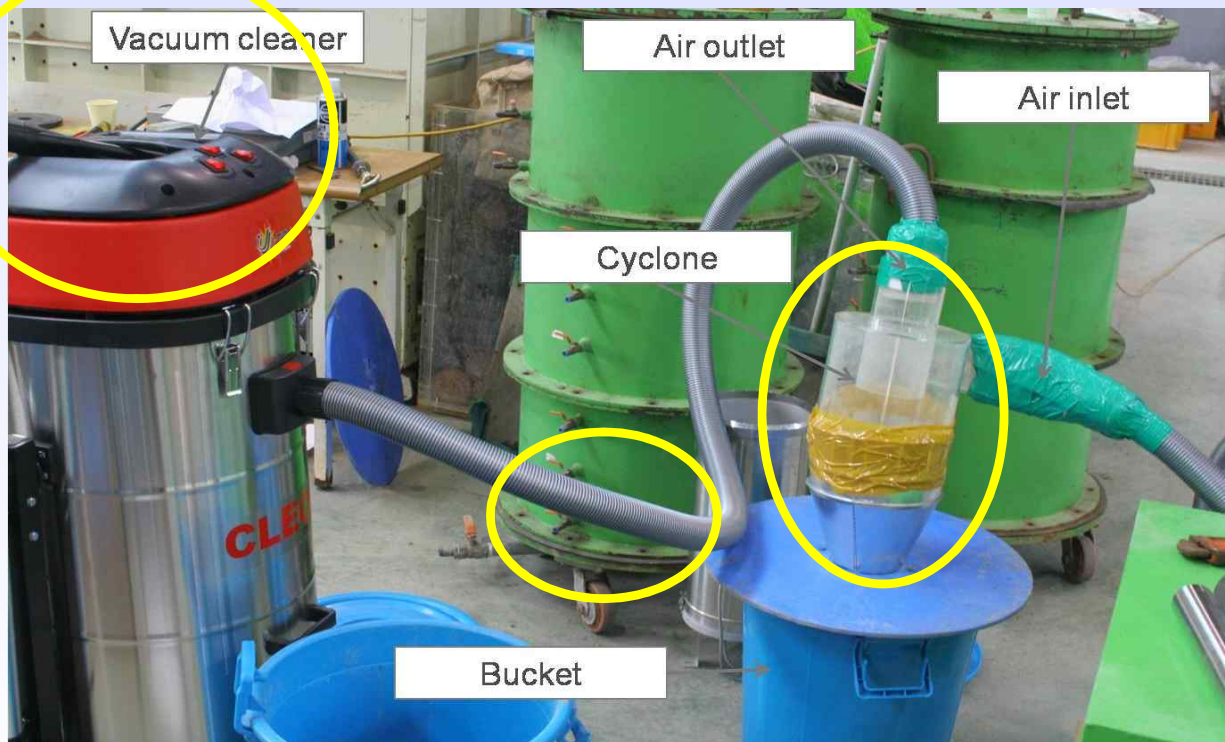


# Need of Pneumatic Transfer & Packing System

## ● Birth of the First Hanyang Pneumatic Transfer System

- Born to drill a borehole for lunar anchoring test
- Did not have a fancy drilling machine ( things around the lab)
- Wanted do save our gold dust

➔ **We've got a nice bore hole, but.....**



**Pneumatic Transportation System**



**Suction Drilling**



# Future Goal



The top of the slide features a decorative header. On the left, a portion of the Earth is visible in space, with a bright star or planet in the background. On the right, a close-up of the Moon's cratered surface is shown.

# Pneumatic Transportation System

# Concept Design

## Terrestrial Pneumatic Conveying System

### ➤ Benefits of Pneumatic Transfer System

- Mature technology with a quite long history
- Closed pipeline against atmosphere
- Transport poisonous and hazardous materials
- Move materials vertically and horizontally



**Pneumatic Conveying in the Flour Mill Facility**



**Prague Pneumatic Post**

**Pneumatic Tube at the Drive Through Bank**

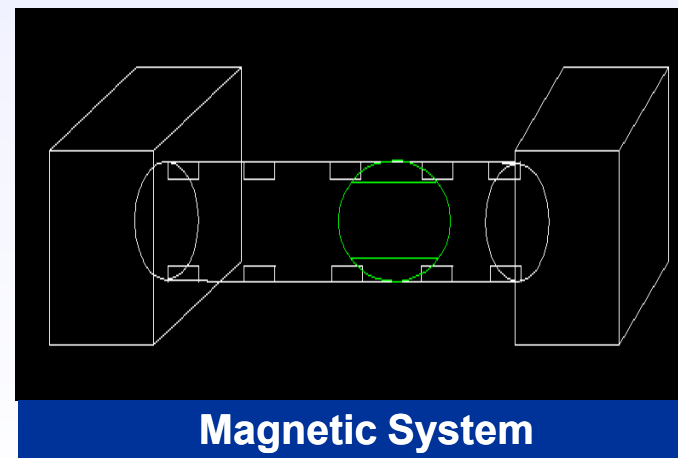
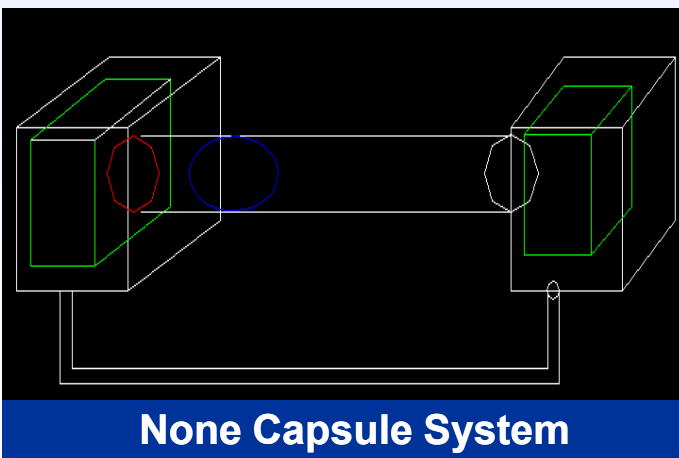
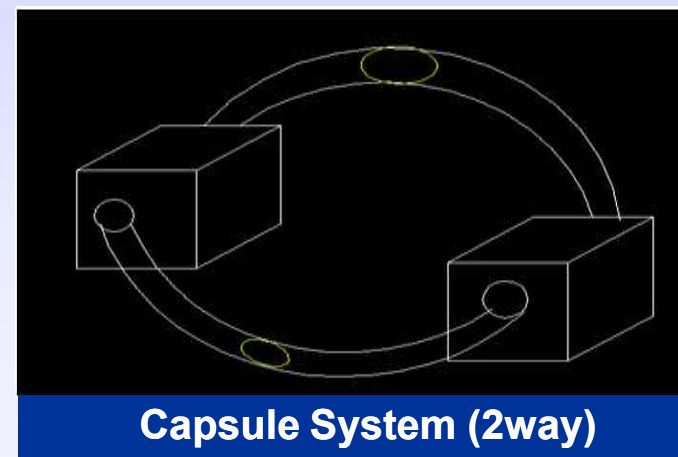
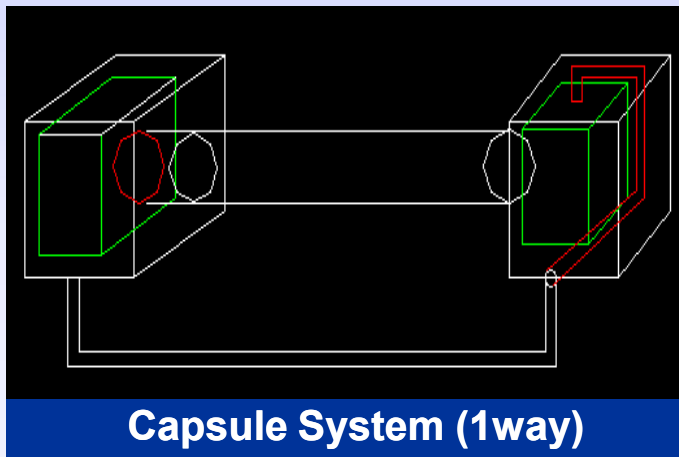




# Concept Design

## Several Types of Closed Pneumatic Transportation Concept

- Due to thin lunar atmosphere, PTS must recycle transfer gas
- Thus, closed system is required



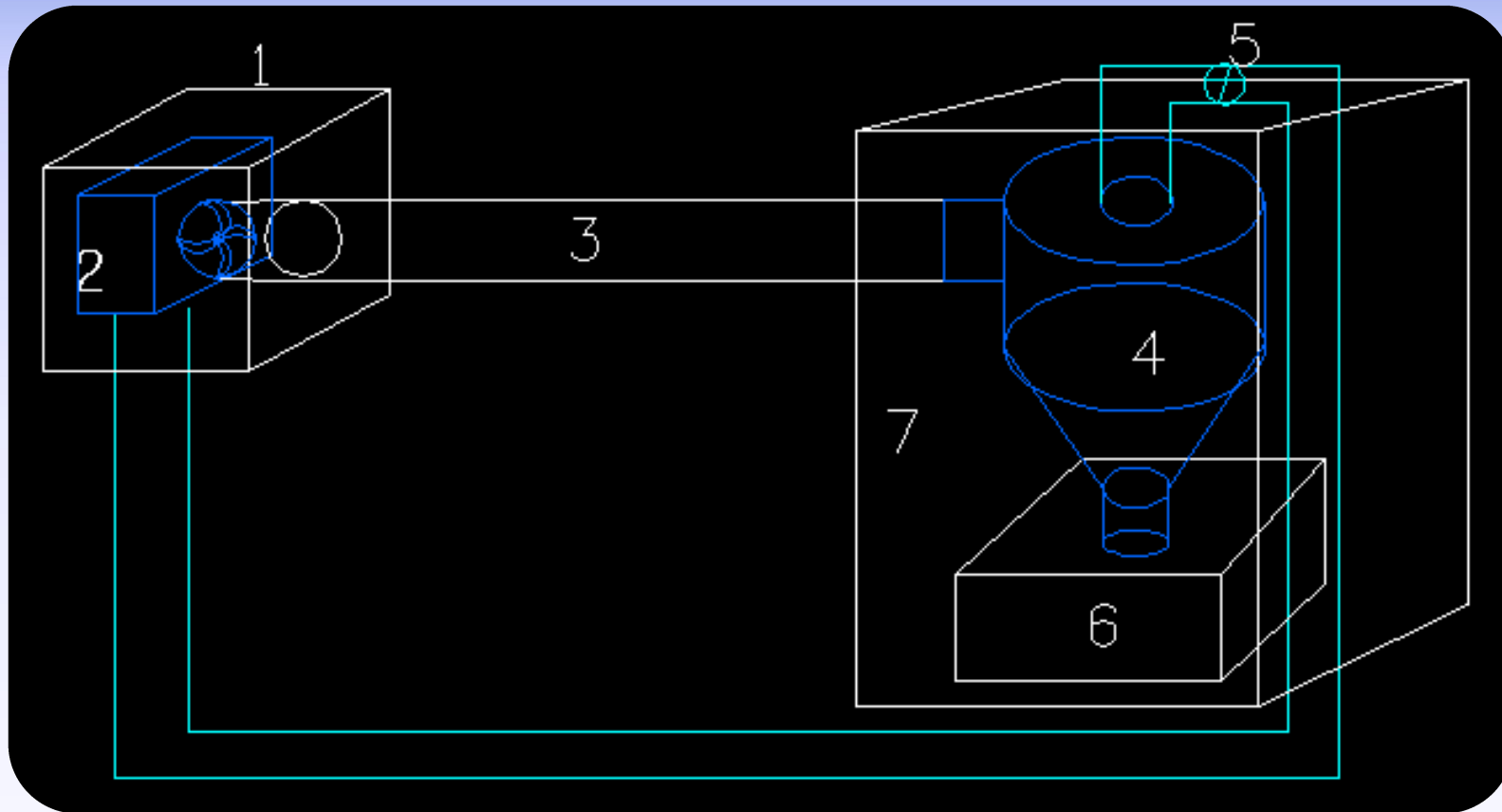
# Concept Design

## Concept Selection

Evaluation Criteria	Weights	Model			
		1way Capsule System	2way Capsule System	Magnet System	None Capsule System
Energy Need	20	2	2	2	3
Easy Construction	15	2	2	1	2
Automation	15	2	3	2	2
Maintenance-Repair	15	2	1	1	2
System Complexity	10	2	2	1	2
Dust control	15	2	2	2	3
Cost	10	1	2	1	2
Total	100	13	14	10	16
Final Value		1.9	2.0	1.5	2.35

# Concept Design

## Conceptual Design of None Capsule System

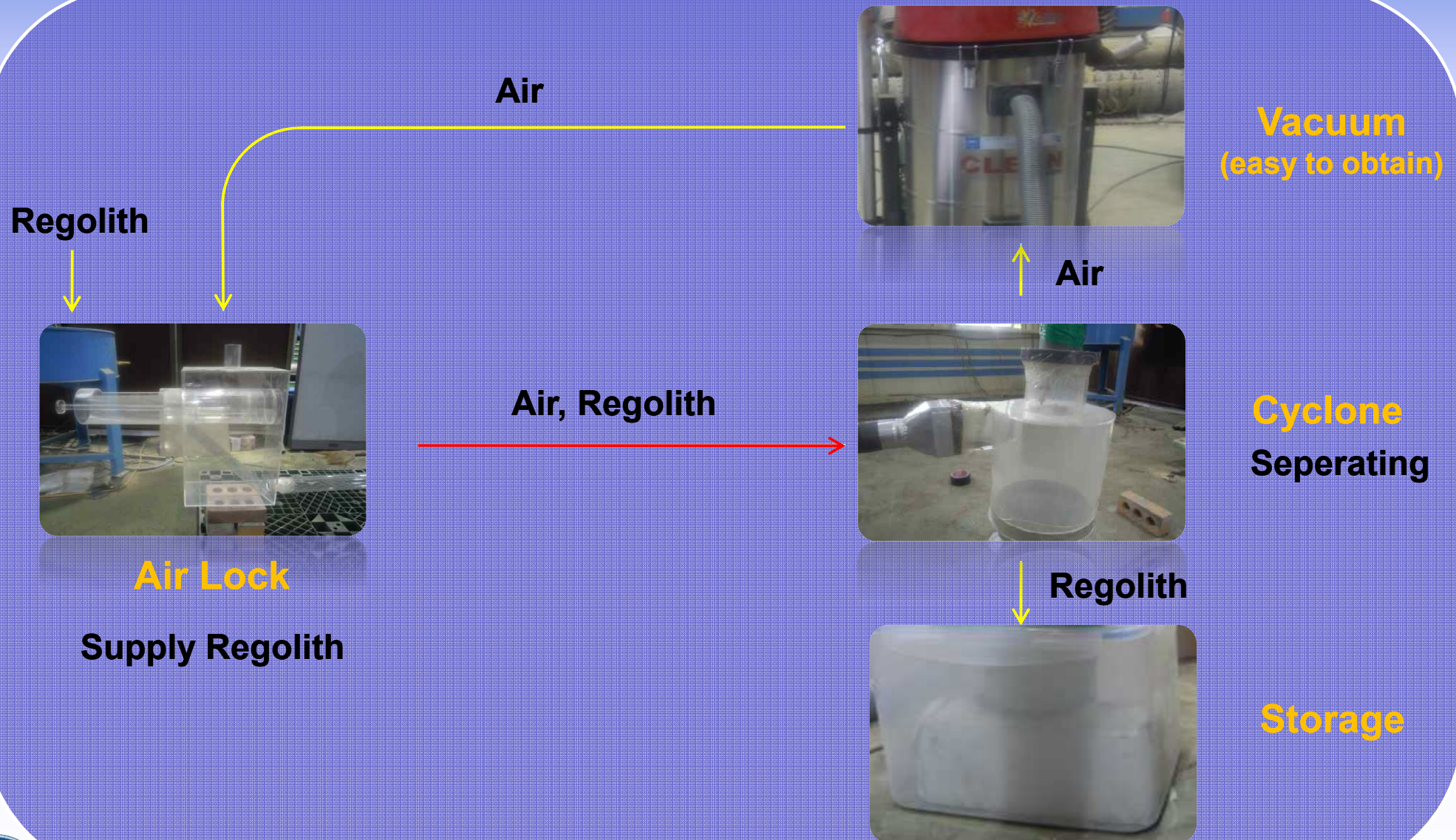


1. Loading Chamber 2. Fan or Compressor 3. Pipeline  
4. Cyclone 5. Filter 6. Storage 7. Supply Chamber



# Concept Design

## ● Preliminary Test on Pneumatic Transportation



# Preliminary Test

## Preliminary Test Factors

### Diameter

- 4.4cm
- 5.5cm
- 6.7cm



### Length

- 1m
- 2m



### Power

- 1power
- 2power



### Angle

- 0°
- 45°
- 90°



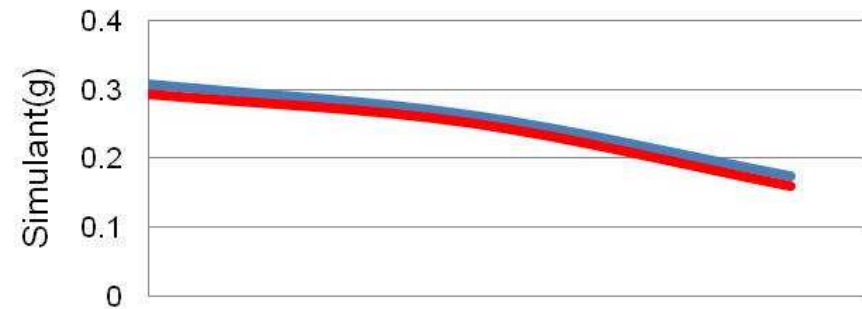
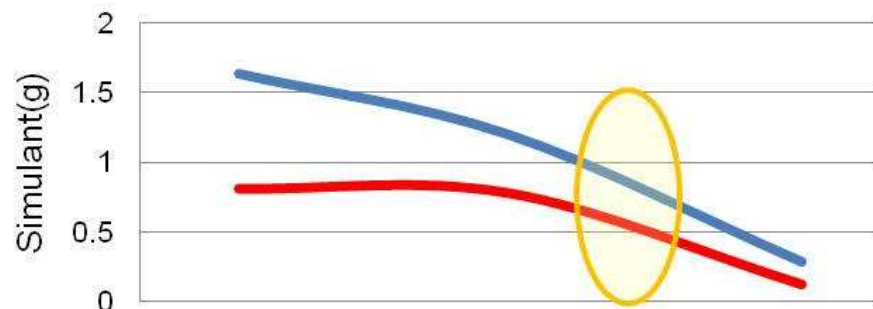
### Location of Cyclone

- - 50cm
- 0cm
- +50cm

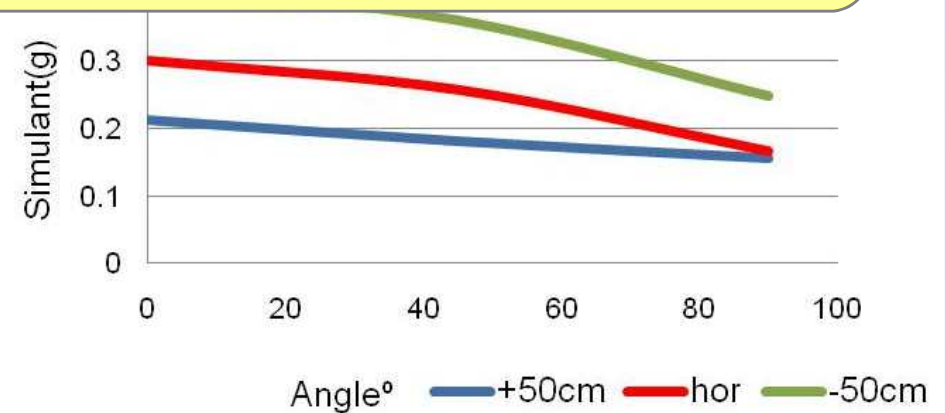
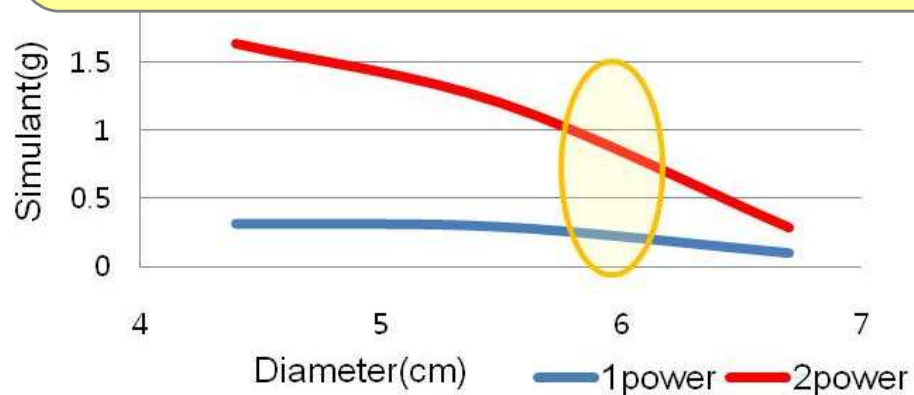


# Preliminary Test

## Preliminary Test Results



**Velocity of the gas (particle) matters!**





# Prototype Development & Testing

## Considerations

- Blowing gas, instead of vacuum suction
- Moon does not have atmosphere → need to recycle gas
- Closed pneumatic transportation system is required

## Key Components



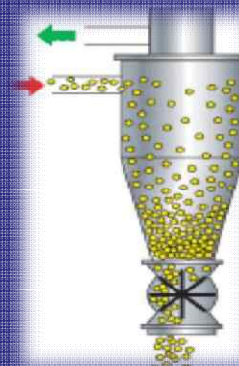
**Ring Blower**  
Inflow Transfer  
Gas into System



**Pipeline**  
Transfer Mixed Flow



**Feeder**  
Input the Transfer  
Material into System



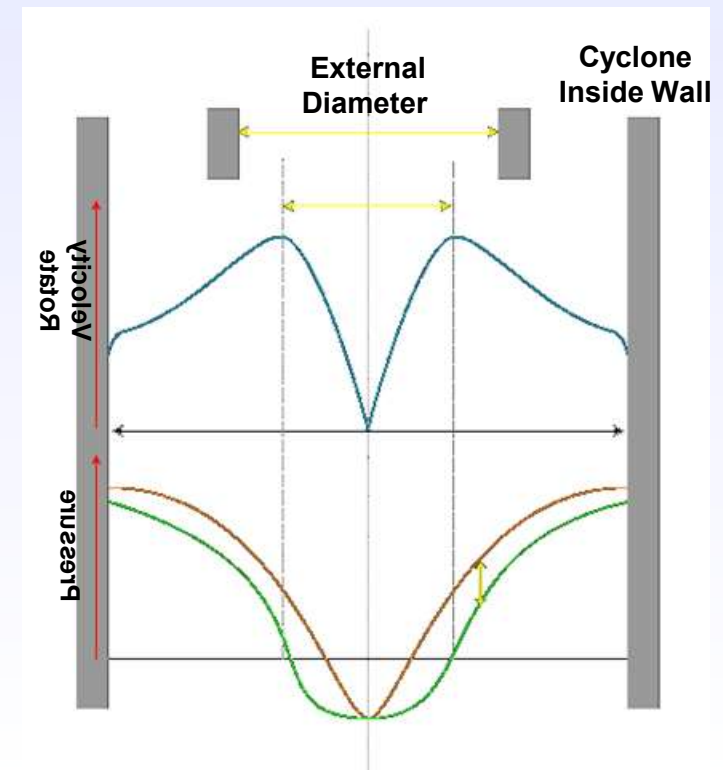
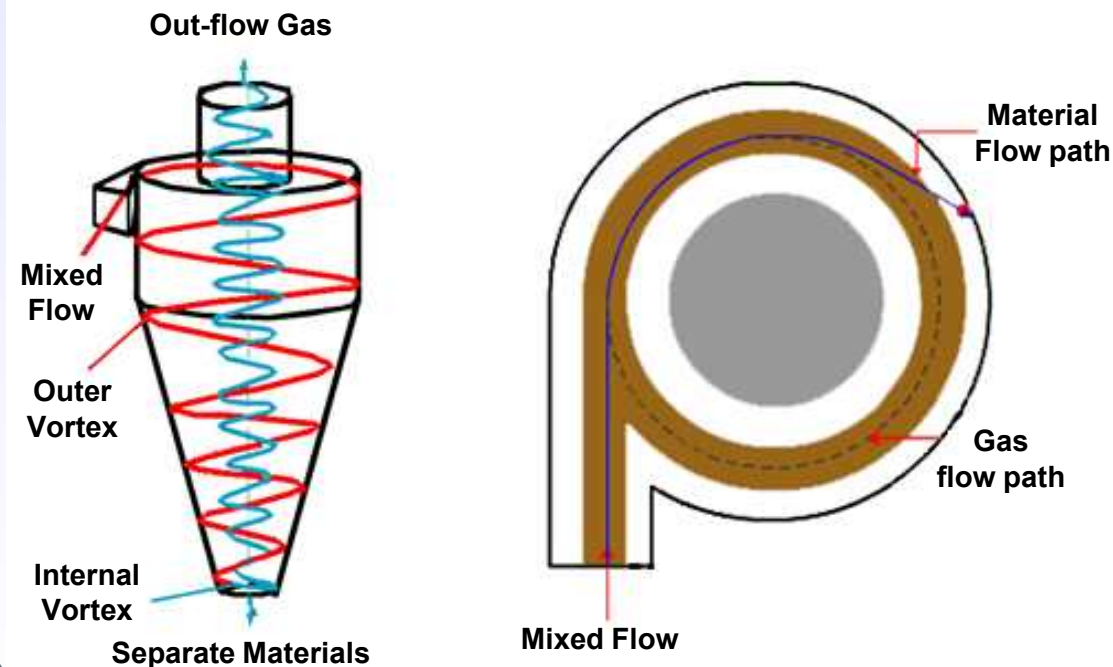
**Separator**  
Separate transferred  
gas and materials by  
centrifugal force

# Prototype Development & Testing

- Cyclone : most essential part for the closed system

## ➤ Separate transfer gas and material

- Cyclone translate linear force into centrifugal force
- Gas and Material have different density
  - ☞ Mixed flow lose their velocity and pressure, cyclone wall captures the particle
  - ☞ Speed and cyclone itself matters, rather than gravity (proper to Moon)



(Pnecon, 2011)

# Pneumatic Transportation System

- Prototype of Pneumatic Transportation System



**c** Pneumatic Transportation System Prototype



# Testing

## Experiment on Material Collection Rate

### Testing Condition

Running Time		1 min
Amount of Material		10Kg
Transfer Length	Blower-Feeder	1m
	Feeder-Angle Pipe	8.5m
	Vertical Pipe	1.8m
	Total Length	11.3m

### Materials



**Thick Particles**  
2mm~



**Midsize Particles**  
0.85mm~2mm



**Fine Particles**  
~0.85mm

# Testing

## ● Testing



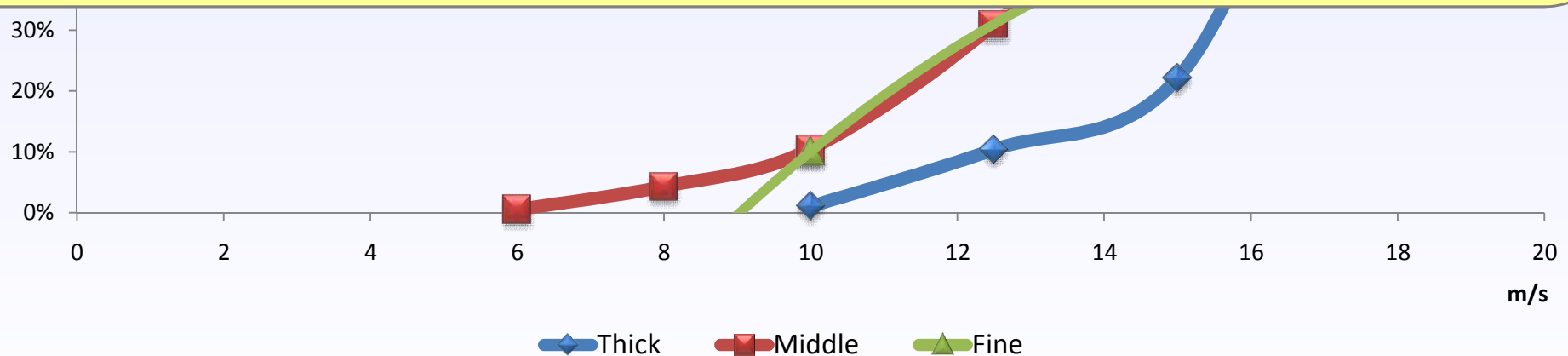
# Testing

## Test Results

Velocity of the gas and particle matters the efficiency

**Fine Particles collection rate was only 50%**

- 👉 leaking from the joints
- 👉 feeder top
- 👉 adhesion to the pipe wall





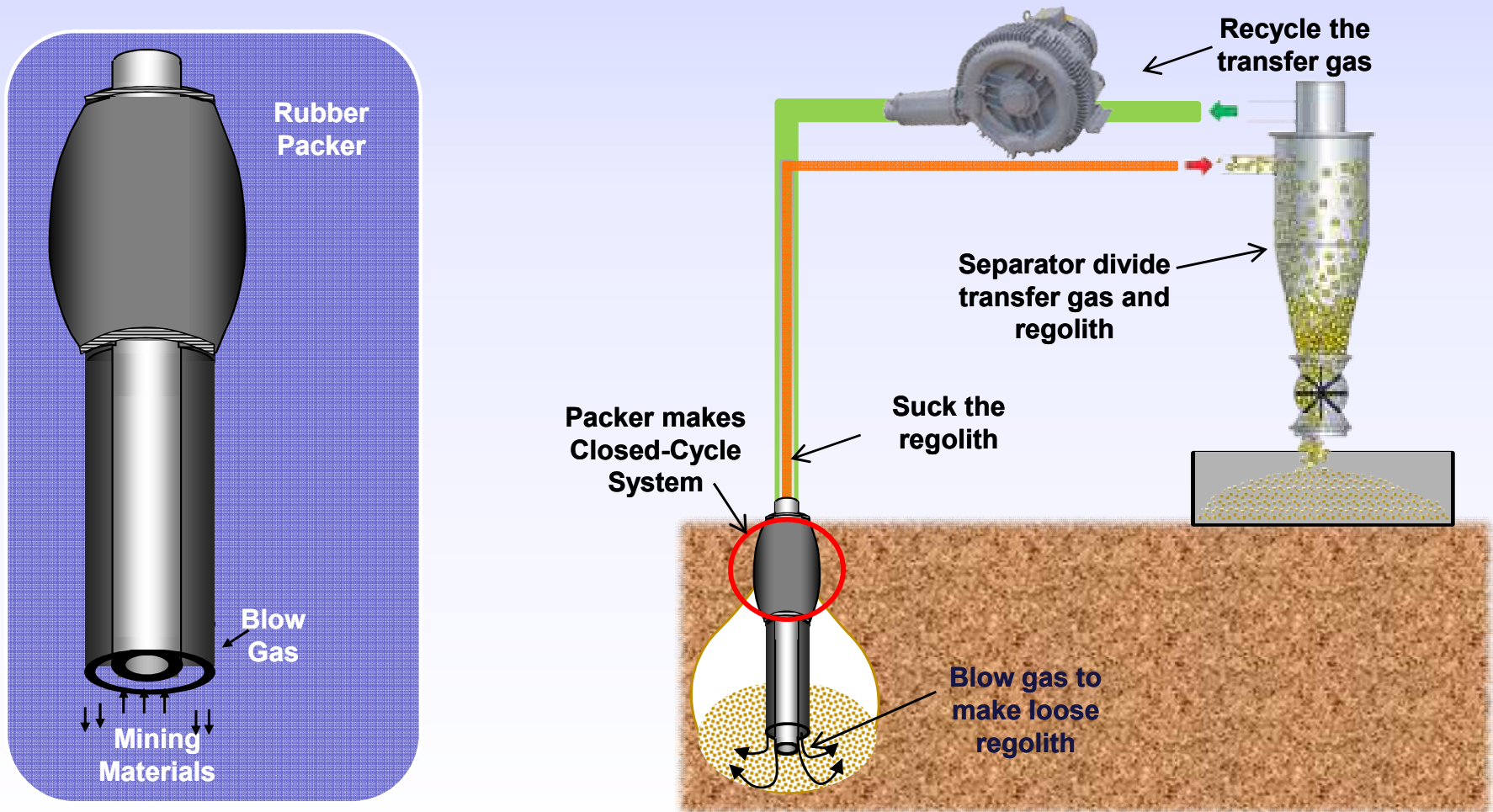
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# Packing System

# Concept Design

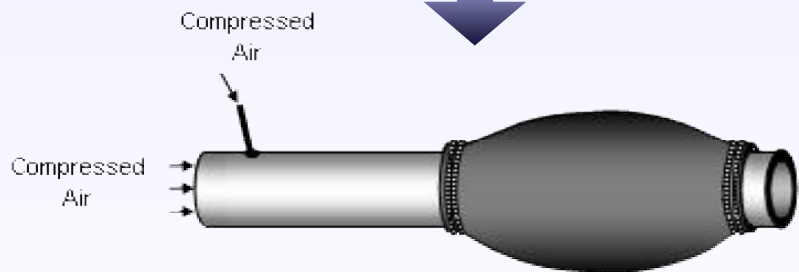
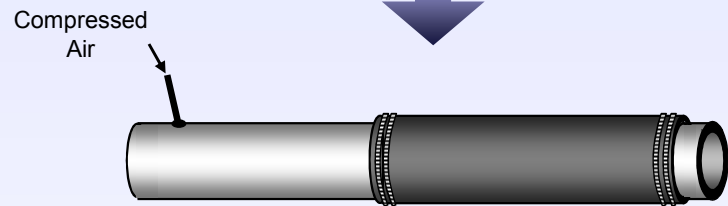
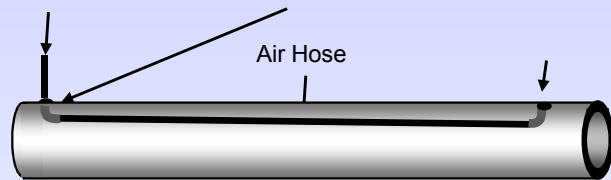
## ● Packing System

- Suction Drilling needs a closed system
- Outer pipeline blow the gas, internal pipeline suck the gas and material
- **Packer has to resist at block the pressure difference**



# Packing System

## ● Design and fabrication of Packer



- Packer provide confined mining area
- Key component of Closed System



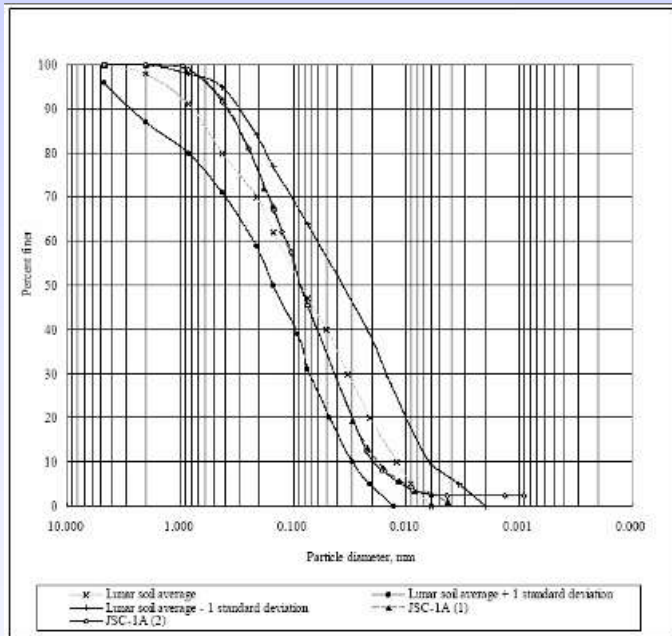
Fabricated Packing System



# Feasibility Testing

## Test Environment

### Lunar Soil



Lunar Soil Size Distribution by Zeng et. al., 2007

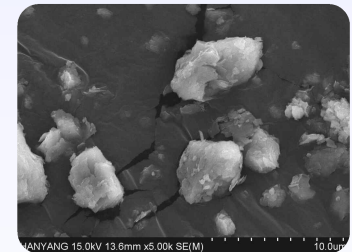
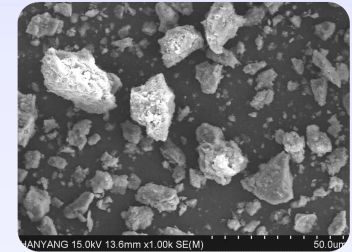
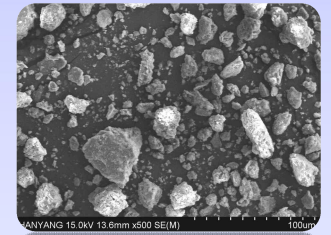
$\Phi = 30 \sim 50$  degrees (Mitchell et. al., 1972)  
 $c = 0.1 \sim 1.0$  kPa (Mitchell et. al., 1972)  
 $\text{SiO}_2 = 46\%$  (Average of Apollo 12 samples)

### KOHLs-1

Sieve Size (#)	Percentage (%)
10	5
20	3
40	10
60	7
100	7.5
200	17.5
Pan	50
<b>Total</b>	<b>100</b>

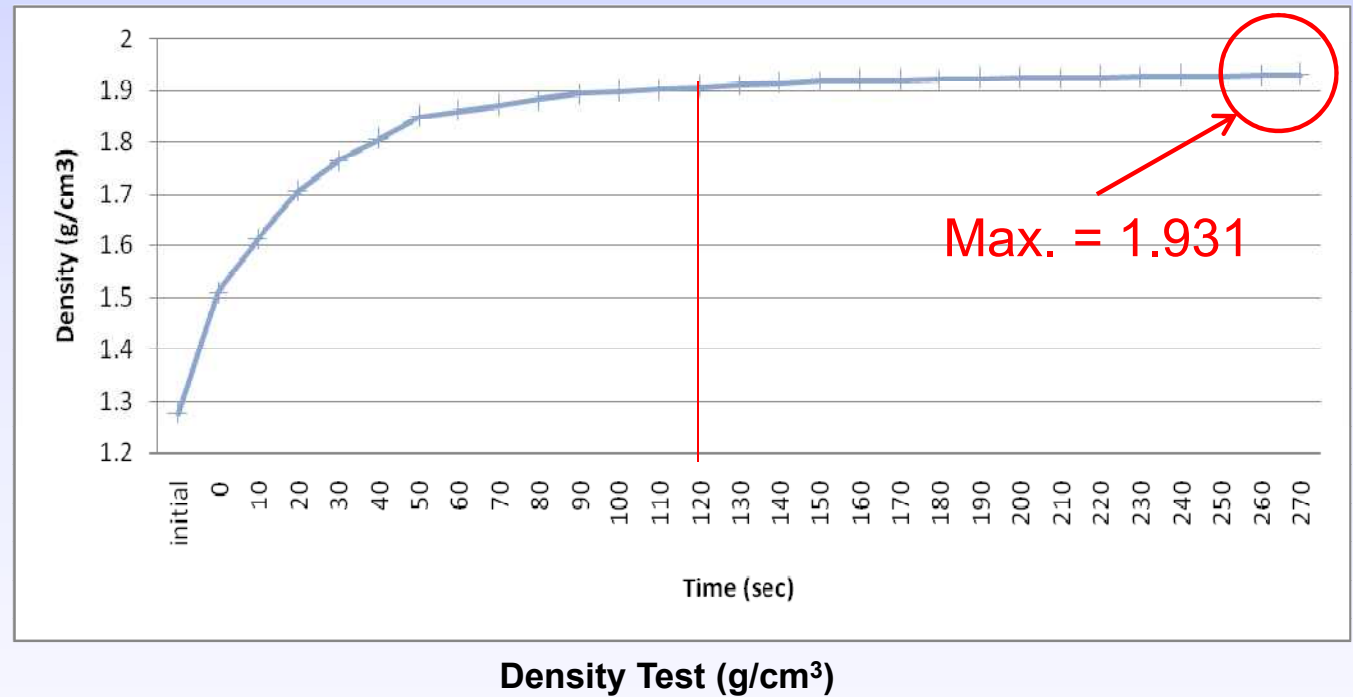
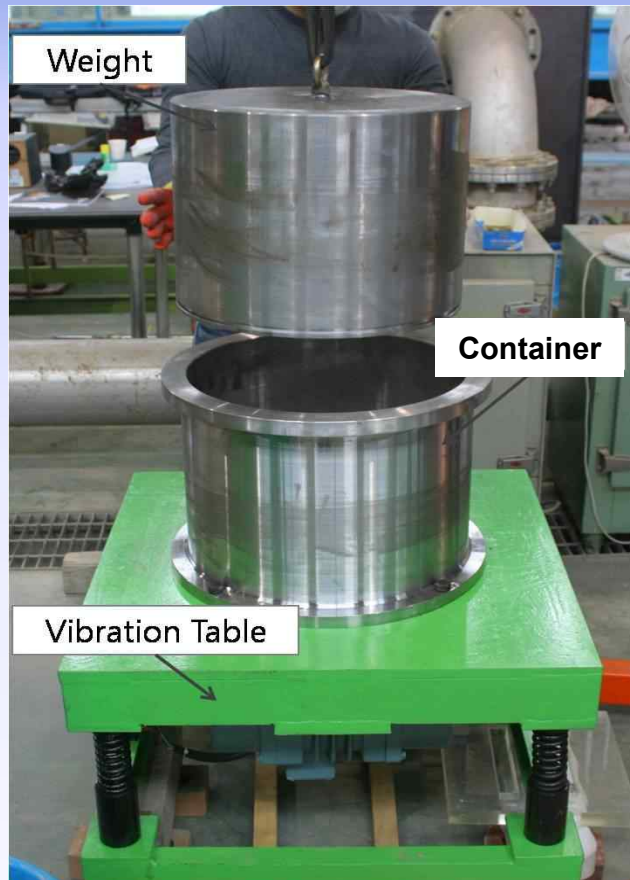
KOHLs-1 Size Distribution

Metamorphic Basalt  
 $\Phi = 37$  degrees  
 $c = 11.8$  kPa  
 $\text{SiO}_2 = 54\%$



# Feasibility Testing

## Test Environment



Bulk Density = 1.7 ~ 1.9 g/cm<sup>3</sup> (Apollo 12 sample, Carrier et. al., 1972)

# Feasibility Testing

## ● Packer Installation



Make the hole



Input



Set up



Open the valve

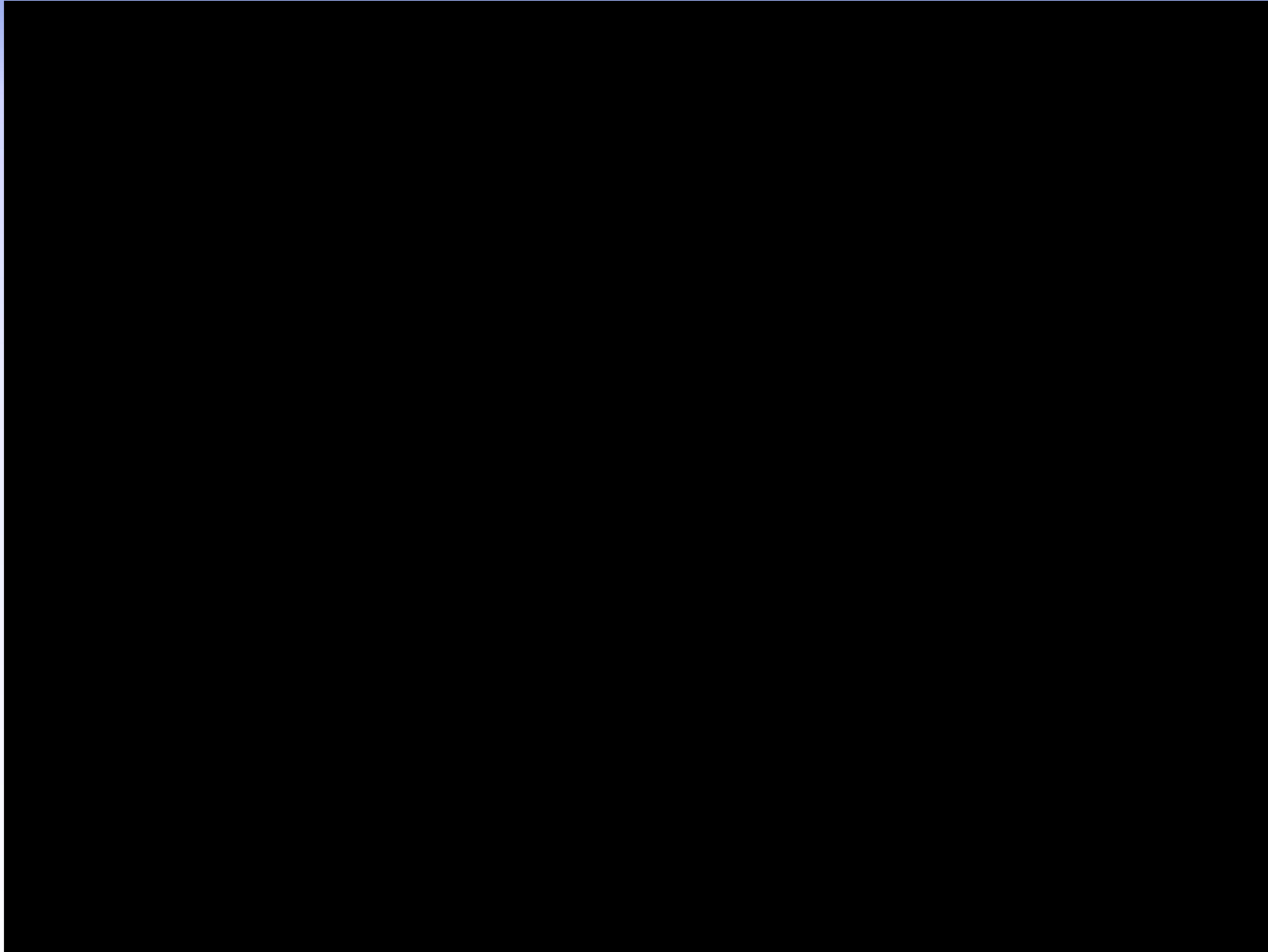


Explode rubber



# Feasibility Testing

- Testing of packer resistance to the pressure difference



# Future Plan

- Merge the Pneumatic Transportation System and Packing System
- Figure out the adhesive materials on the pipe wall
- Additional Separator for the finest material (under 100micrometer)
- Experimental study for suction drilling by using packing system
- Experimental study for mining & transportation efficiency
- Effect of the Packer in the vacuum condition (leak, bearing force, etc)

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# Thank You!